Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

64.9
31 C
ARS 34-73

CROPS RESEARCH

ARS 34-73
August 1965

BRANCH

The Response of Waterstargrass to Herbicides

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Some chemicals used for weed control can be injurious to man if handled carelessly. They can also be injurious to desirable plants, livestock, wildlife, and fish if improperly applied. Care should be exercised in the use of herbicides to avoid polluting streams and water supplies. Precautions for handling and applying that are printed on the container label should be followed.

Mention of a proprietary product in this publication does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval by the Department to the exclusion of other products that may also be suitable.

THE RESPONSE OF WATERSTARGRASS TO HERBICIDES[1/]

E. B. Hollingsworth and R. E. Wilkinson, Crops Research Division

INTRODUCTION

Though present for more than 200 years, only since 1950 has waterstargrass, as a submersed weed, been recognized as an economic nuisance. A recent review of the literature[2/] showed that waterstargrass, Heteranthera dubia (Jacq.) MacM., has a long history of identification and a wide distribution.

In connection with studies on the nature and control of waterstargrass in northeastern Arkansas,[3/] the response of the plant to selected chemical applications was observed. Conditions in the field were usually restrictive for the best application of the herbicides. Waterstargrass developed in flowing water of several inches to several feet in depth. Liquid herbicides were rapidly diluted and carried away by the current, whereas pelleted materials were not released in a manner sufficient to build up a lethal concentration. Control of waterstargrass by chemicals was further complicated by its relatively high tolerance to systemic herbicides. Compounds exhibiting contact toxicity gave promise of a more practical approach to control of the weed.

The common and chemical names of all compounds tested during the studies are listed in table 1. Elsewhere in the report common names only are used when available.

PROCEDURES AND RESULTS

Field Experiments

The first application of herbicides to waterstargrass utilized small, semiconfined plots in Honey Cypress Slough in 1957. Metal rectangular caissons 2 by 4 feet in area and 5 feet deep, open top and bottom, were placed in the weed-infested stream. The treatments consisted of eight herbicides at four concentrations each in three replications. The herbicide concentration was calculated on the volume of water in the caisson. The materials were applied and the weed within the caisson exposed to the treatment for 30 minutes before the box was removed and the current permitted

---

1/ Investigations conducted in cooperation with the Arkansas Agricultural Experiment Station and Delta Substation, Clarkedale, Ark. This report is the final summary of a research project at Clarkedale on the effects of herbicides on waterstargrass.

2/ Hollingsworth, E. B. The nature and distribution of waterstargrass, Heteranthera dubia (Jacq.) MacM. /In press./ 1965.

3/ Hollingsworth, E. B. Waterstargrass as an aquatic weed. Ark. Expt. Sta. Bul. /In press./ 1965.

TABLE 1.--The common and chemical names of materials investigated for their herbicidal activity on waterstargrass. Where no common designation was available, the full chemical name is used

Common name or designation	Chemical name
2,4-D, amine	2,4-dichlorophenoxyacetic acid, dimethylamine salt
2,4-D, BE	2,4-dichlorophenoxyacetic acid, butoxyethanol ester
2,4-D, IO	2,4-dichlorophenoxyacetic acid, isooctyl ester
Na-2,4-D	2,4-dichlorophenoxyacetic acid, sodium salt
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-T, BE	2,4,5-trichlorophenoxyacetic acid, butoxyethanol ester
2,4,5-T, IO	2,4,5-trichlorophenoxyacetic acid, isooctyl ester
acrolein	acrylaldehyde
aromatic oil "1"	Phillips Aromatic Oil "D"
aromatic oil "2"	Richfield Aromatic Oil "A"
CIPC	isopropyl-N-(3-chlorophenyl)carbamate
CP-522	trichlorophenylacetonitrile
dalapon	2,2-dichloropropionic acid, sodium salt
dicamba	2-methoxy-3,6-dichlorobenzoic acid, dimethylamine salt
dichlobenil	2,6-dichlorobenzonitrile
diquat	6,7-dihydrodipyrido(1,2-a:2',1'-c)-pyrazidiinium salt
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
DMTT	3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione
DSMA	disodium methylarsonate
endothall	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid
erbon	2(2,4,5-trichlorophenoxy)-ethyl-2,2-dichloropropionate
fenac	2,3,6-trichlorophenylacetic acid, sodium salt
fenuronTCA	3-phenyl-1,1-dimethylurea trichloroacetate
isocil	5-bromo-3-isopropyl-6-methyluracil
PBA	polychlorobenzoic acid
picloram	4-amino-3,5,6-trichloropicolinic acid
silvex, BE	2(2,4,5-trichlorophenoxy)propionic acid, butoxyethanol ester
silvex, PGBE	2(2,4,5-trichlorophenoxy)propionic acid, propylene-glycolbutylether ester
simazine	2-chloro-4,6-bis(ethylamino)-s-triazine
----------	O-dichlorobenzene
----------	2,6-dichlorobenzamide
----------	50 percent abiethylamine acetate
----------	25 percent polychlorobenzoic acid
----------	disodium ethylene bisdithiocarbamate
----------	diisobutylphenoxyethoxyethyldimethylbenzyl ammonium chloride
----------	methyl dodecylbenzyl trimethyl ammonium chloride
----------	octylphenoxyethoxyethyldimethyl p-chlorobenzyl ammonium chloride

to displace the herbicide not absorbed by the plants. Table 2 lists the herbicides and concentrations used and the plant response.

TABLE 2.--Response of waterstargrass 7 days after a 30-minute exposure to the materials and concentrations listed, Honey Cypress Slough, 1957[1/]

Herbicide	Concentration[2/]	Response	Herbicide	Concentration[2/]	Response
	P.p.m.			P.p.m.	
50 percent abiethylamine acetate	0	0	Aromatic oil 1	0	0
	25	6.0		50	6.7
	100	8.3		200	10.0
	200	10.0		400	9.3
2,4-D amine	0	0	Aromatic oil 2	0	0
	1	1.0		50	10.0
	10	5.3		200	9.3
	100	9.3		400	10.0
25 percent polychloro-benzoic acid	0	0	Emulsified O-dichlorobenzene	0	0
	1	0		50	6.7
	10	5.0		100	6.7
	100	10.0		200	10.0
Dalapon	0	0	Nonemulsified O-dichloro-benzene	0	0
	50	1.0		50	0
	100	6.0		100	0
	200	5.0		200	3.3

1/ The ratings (0 = no response, 10 = all leaves and stems dead) are an average of three replications.

2/ Concentrations expressed as parts per million by weight acid equivalent or active ingredient.

None of the treatments exhibited an effect within 24 hours. The materials and concentrations that were active produced maximum response within 7 days. Inasmuch as 2.7 pounds of chemical per acre-foot of water is required for 1 p.p.m., it is apparent that the amount of these materials necessary to give acceptable control in flowing water would not be economically practical. In this first test, two systemic herbicides, 2,4-D and polychlorobenzoic acid, appeared effective at 100 p.p.m. The emulsified O-dichlorobenzene was at least three times as effective as the nonemulsified material.

Pelleted formulations of CIPC and the BE ester of 2,4-D were applied to waterstargrass in Little Slough ditch on May 15 and September 15, 1959, at rates of 20 and 40 lb./acre each in three replications. On the first date the weed was 2 to 4 feet long and growing vigorously in water up to 4 feet deep. For the September application the water was only 2 feet deep and the

plants had matured, shed their leaves, and the bare stems were lying on the bottom with green shoots at the nodes.

The plants treated in May continued to develop throughout the season with no formative effects or stand reduction indicated. The only herbicidal response noted in the test was observed 4 weeks after the fall application. At that time the water level had fallen to expose the old denuded plant stems in the mud near the water edge. These old stems were producing new shoots from the nodes in the control plots. This new growth was prevented by the 40-lb./acre rate of 2,4-D and CIPC and was greatly inhibited at the 20-lb./acre dosage.

Exceptionally high rates of four herbicides were applied to waterstargrass in Cocklebur Slough to test the feasibility of controlling the weed in flowing water. There was approximately a 75-percent weed infestation in water 2 feet deep and flowing at a rate of 20 cubic feet per second (c.f.s.). One quart of diquat was injected into the water over a 150-sq.ft. area for an initial rate of 240 lb./acre. Granular endothall was applied to 600 sq.ft. for an initial rate of 42 lb./acre. The isooctyl esters of 2,4-D and 2,4,5-T were each applied on granules to 600-sq.ft. areas for an initial rate of 280 lb./acre. Fine dustlike particles from the phenoxy materials lodged on the plant material that lay on, or extended above, the water surface. The rates are designated "initial" because the moving water rapidly diluted and carried away much of the herbicides.

The lack of response to the excessive rates of herbicide was noteworthy. Diquat had little or no effect, probably due to the high silt content associated with the weed and its environment. Endothall had no effect. It is primarily a contact toxicant and, should it be slowly released from the granules, the current probably would prevent the accumulation of sufficient material to be effective. Where 2,4-D and 2,4,5-T came in contact with waterstargrass at the water surface, they caused death and deterioration of the plant material. However, there was apparently no lethal translocation of the herbicides, as the waterstargrass plants were not affected from the water surface to their base in the soil.

Acrylaldehyde (acrolein) was applied to a drainage ditch infested with waterstargrass and species of Myriophyllum, Jussiaea, and Potamogeton. Twenty-five gallons of the material was injected into the water in August at a single location. The rate of waterflow was approximately 8.5 c.f.s. After 1 month the weedy vegetation had died and disintegrated for approximately 2 miles below the point of treatment. Excellent temporary control was obtained for the species listed. Figure 1 shows the condition of the channel at the time of treatment and 1 month later.

Greenhouse and Laboratory Experiments

Early greenhouse studies compared the response of waterstargrass to herbicides while the plants were growing in Hoagland and Arnon nutrient solution. Four concentrations of each herbicide material was applied, along with a control, in three replications. The plant sections were permitted to grow in the nutrient-herbicide solution for 2 weeks. The herbicides and

Figure 1.--Before (top) and 1 month after (bottom) acrolein was applied to ditch infested with waterstargrass and other weed species.

concentrations, along with the increase in plant weight for each treatment, are shown in table 3.

The phenoxy herbicides are considered among the more active systemic materials; however, they seldom produced more than a 50-percent inhibition of waterstargrass even at the 10^{-3}M concentration. The exception was the PGBE ester of silvex. The validity of this result is questionable, since the high activity of PGBE silvex was not indicated in the lower concentrations. CIPC was surprisingly active in view of the fact that waterstargrass seems to

resist systemic materials. Polychlorobenzoic acid and DMTT seemed to warrant further testing. Diquat and endothall were active as contact toxicants. The sodium salt of 2,4-D had little effect on waterstargrass. In fact, it appeared to stimulate the growth of the plant when used in combination with dalapon at the lower concentrations.

Three formulations of ammonium chloride and one of a thiocarbamate were applied to waterstargrass growing in nutrient solution. Four herbicides at four concentrations and a control were included in the three replications. The plant material was exposed to the treatments for 2 weeks in 1-quart mason jars. The herbicides, concentrations, and increase in plant weight for each treatment are shown in table 4.

TABLE 3.--Response of waterstargrass to herbicides while growing in nutrient solution, Clarkedale, Ark.[1/]

Trial and herbicide	Increase in plant weight for--				
	Control	Herbicide concentration (molar)			
		10^{-6}	10^{-5}	10^{-4}	10^{-3}
	Grams	Grams	Grams	Grams	Grams
Trial No. 1:					
2,4-D, BE ester	4.5	3.6	3.6	3.9	2.2
2,4,5-T, BE ester	3.9	4.4	3.4	3.4	1.7
Silvex, BE ester	6.0	6.2	5.1	5.6	3.3
Polychlorobenzoic acid	7.0	6.0	5.2	3.5	1.2
Endothall	6.5	4.4	4.2	.4	1.4
Trial No. 2:					
Dalapon	1.5	1.4	1.2	.9	1.0
Erbon	.6	.8	.4	.2	.2
Silvex, PGBE ester	.7	.9	1.0	.6	0
2,4,5-T	.5	.9	.7	.7	.3
Trial No. 3:					
Dalapon	3.7	3.1	3.5	2.4	.6
Diquat	3.2	2.4	1.3	.8	.2
DMTT	2.1	2.8	3.0	1.2	.5
Trial No. 4:					
CIPC, emulsion	.8	.5	.3	0	- .1
CIPC, granular	.4	.3	.4	.1	- .1
Na-2,4-D, granular	.4	.5	.3	.4	.3
Na-2,4-D dalapon, granular	1.7	2.1	2.4	1.7	1.4

1/ Averages for three replications.

TABLE 4.--Response of waterstargrass following a 2-week exposure to the herbicides listed, Clarkedale, Ark.[1/]

Herbicide	Increase in plant weight for--				
	Control	Herbicide concentration (p.p.m.)			
		1	2	4	8
	Grams	Grams	Grams	Grams	Grams
Diisobutylphenoxyethoxyethyl-dimethylbenzyl ammonium chloride	0.6	0.4	0.3	0.2	0.04
Methyl dodecylbenzyl trimethyl ammonium chloride	.8	.5	.5	.3	.13
Octylphenoxyethoxyethyldimethyl p-chlorobenzyl ammonium chloride	.3	.2	.4	.2	.14
Disodium ethylene bisdithio-carbamate	.3	.4	.2	.3	.27

1/ Three replications per treatment.

The materials were unsatisfactory, especially the thiocarbamate. The ammonium chlorides required 4 to 8 p.p.m. in a closed container to produce fair to good growth inhibition in waterstargrass. Effective rates would not be practical in field application.

Nine herbicides, at a single rate each, were applied to waterstargrass plants growing under controlled light and temperature conditions. The experiment was conducted in a 60-cu.ft. reach-in-type refrigerator adapted as a growth chamber. Light was provided by four 40-watt fluorescent tubes, one each of red and blue and two cool white. The temperature was maintained at 78° to 80° F. The treatment vessels were of 1-liter capacity and contained equal amounts of soil and water. Two weeks after transplanting, the waterstargrass plants were exposed to the herbicides applied to the water. After 14 days the plants were rated for response and the treated water replaced with fresh untreated water. Two weeks later the plant response was again noted, the plant material harvested, and the weights recorded. At this stage the test vessels, with only the plant roots in the soil, were removed from the growth chamber and placed on a greenhouse bench. One month later the plants showing regrowth were again harvested and weighed. Table 5 shows the materials and rates used along with the yield data.

Dichlobenil, dicamba, and isocil were ineffective for waterstargrass control. Isocil, more than 50 percent effective initially, permitted the most regrowth. CP-522 was slow acting initially but inhibited regrowth. Diuron, DSMA, fenac, endothall, diquat, and CP-522 appear promising for waterstargrass control in nonflowing water.

Waterstargrass plants were exposed to 10 p.p.m. of the isooctyl ester of 2,4-D for 1, 4, 7, and 14 days. The experiment was conducted in a walk-in

TABLE 5.--Comparative response of waterstargrass after a 14-day exposure to the herbicides and rates shown and regrowth 1 month after crop harvest, Clarkedale, Ark.[1/]

Compound	Rate	Plant response		Weight increase		Regrowth	
		2 wk.	4 wk.	Average	Percent of control	Length	Weight
	P.p.m.			Grams		Inches	Grams
Dichlobenil	2	3	4	4.5	93	4	7
Dicamba	2	1	3	4.1	85	7	8
Fenac	5	6	7	1.5	31	0	0
CP-522	5	3	9	3.4	71	0	0
Endothall (na-salt)	5	7	8	2.1	44	0	0
Isocil	5	2	7	1.7	36	6	11
Diuron	5	7	10	.2	4	0	0
Diquat	2	8	9	.6	13	1	1
DSMA	10	6	8	.6	13	0	0
Control	---	1	2	4.8	100	6	9

1/ Average of three replications; rating of 0 = no response and 10 = all plants dead.

refrigerator converted to a growth chamber. The temperature was maintained at 78° to 80° F. with a light period of 12 hours per day. Test vessels were 2-gallon glass aquaria, each containing an equal amount of soil and water. Three replications were utilized. Three weeks after the waterstargrass cuttings were transplanted into the aquaria, all containers except the control received the 10-p.p.m. rate of 2,4-D. The treated water in one vessel for each replication was replaced with fresh untreated water after 1 day, 4 days, 7 days, and 14 days. Four days after the last treatment period, the plants in each aquaria were harvested and weighed (table 6).

TABLE 6.--Reduction in vegetative development of waterstargrass exposed to 10 p.p.m. of the isooctyl ester of 2,4-D for the periods indicated, Clarkedale, Ark.[1/]

Treatment period	Increase in plant growth		Yield reduction
	Average	Percent of control	
	Grams		Percent
1 day	17.4	82	18
4 days	14.6	69	31
7 days	15.6	74	26
14 days	9.8	46	54
Control	21.2	100	0

1/ Averages of three replications.

The results of the experiment indicate that waterstargrass is not readily killed by 2,4-D. There was an increased yield reduction as the time of exposure was increased, but a marked effect on the weed was noted only with the 14-day period. With waterstargrass plants, reduction in vegetative yield is not often a good criteria of the plants control. Severely retarded plants are capable of making rapid and healthy growth once they are removed from the presence of the herbicide.

The preceding experiment was followed with a test in which waterstargrass plants were exposed to three rates of the isocotyl ester of 2,4-D for 5 weeks. The aquaria were again prepared with equal amounts of soil and water and divided into three replications. One month after the vegetative cuttings were embedded in the soil, the treatment aquaria received the 2,4-D at rates of 5, 10, and 20 p.p.m. Five weeks later the plant material was harvested and the wet weight recorded. Immediately after weighing, the harvested material was replanted in fresh, untreated soil and water. Eight weeks after the replanting, the regrowth material was harvested and weighed. All data are shown in table 7.

TABLE 7.--Response of waterstargrass after 5 weeks' exposure to the IO ester of 2,4-D at three concentrations, the initial weed control, and the regrowth after the harvested material was replanted, Clarkedale, Ark.1/

2,4-D (p.p.m.)	5 weeks after treatment		Regrowth 8 weeks after replanting		
	Weight increase	Percent of control	Fresh weight	Dry weight	Percent of control
	Grams		Grams	Grams	
5	23.8	72	17.6	1.6	100
10	21.7	65	16.6	1.5	94
20	13.4	40	14.6	1.2	75
Control	33.2	100	15.4	1.6	100

1/ Averages of three replications.

After 5 weeks' exposure to the herbicide in still water, waterstargrass survived the higher rate of 2,4-D. With 60-percent initial control at 20 p.p.m., the plants recovered and produced 75 percent as much material as the control in 8 weeks. Three days after application, waterstargrass exhibited a marked response pattern to the 2,4-D. At 5 p.p.m., the terminal internode had some curvature and was completely etiolated. The second, third, and fourth internodes were etiolated for a few millimeters above their base node. The length of this etiolation became progressively shorter from the second to the fourth internode. The terminal leaves were pale to slightly chlorotic for a few millimeters at their base. No lower leaves were affected. At 10 p.p.m., the progressive response from the terminal toward the base of the plants also applied but was noticeably more advanced than at

the lower dosage. In many of these plants the entire second internode was etiolated with the basal etiolation extending to the fifth and sixth internode. In addition, the leaves of the second node were also chlorotic at their base. At 20 p.p.m., the trend of effect was the same but was more advanced basipetally. It was concluded that, at concentrations which do not inflict mechanical injury, 2,4-D exhibits a toxicity to waterstargrass that is revealed by a progressive chlorosis of stem and leaf tissue. The response indicates that the activity is greater at the terminal nodes and leaves, and at a given dosage becomes less effective basipetally. An increase in dosage will extend the chlorotic response basipetally.

Simazine was applied to waterstargrass at rates of 0.5, 1.0, 2.0, and 4.0 p.p.m. in three replications 2 days after the plants had become rooted in the soil of 5-gallon containers. The herbicidal solutions remained in contact with the plants for 18 days before being removed and replaced with fresh untreated water. A plant response rating was made at 3 and 5 weeks after treatment. The plant material was harvested and weighed after 5 weeks (table 8).

TABLE 8.--Response of waterstargrass exposed to four rates of simazine in three replications for 18 days: 0 = no response, 10 = all dead, Clarkedale, Ark.[1/]

Simazine concentration (p.p.m.)	Response rating after-- 3 weeks	5 weeks	Weight
			Grams
0.5	0	1	20
1.0	5	10	0
2.0	5	10	0
4.0	8	10	0

1/ Rating is based on the amount of chlorotic and dead tissue.

Waterstargrass was susceptible to simazine under the conditions of this test. The plants exposed to 0.5 p.p.m. showed a slight response but recovered to produce a good yield. The three higher rates were lethal to the weed.

FenuronTCA and diuron, herbicides usually active through the root system, were tested as soil treatments for the control of waterstargrass. Two large flat pans, containing 2 inches of soil plus 1 inch of water, had developed a very dense mat of the prostrate-type of waterstargrass. The area of each pan was partitioned into four sections of 3 sq.ft. each. This permitted the application of three rates of the herbicide and a control for each pan, and thus, with the two pans, allowed two replications. The fenuronTCA pellets were first injected into the soil in a precise distribution

to give 5, 10, and 20 lb./acre of the active material. The treated plants were observed for 3 months. At that time the soil was injected systematically with a solution of diuron to give rates of 1, 2, and 4 lb./acre, respectively, in the previous treatments of 5, 10, and 20 lb./acre of fenuronTCA. The plants were observed for 6 months after the diuron treatments.

Waterstargrass did not exhibit a response to fenuronTCA within the 3-month period. For several weeks after the diuron was added there was no response. After 2 months a noticeable darkening and dying of some foliage occurred; however, new growth appeared almost as fast as the old foliage died. After 6 months the weed infestation had been reduced 20, 60, and 90 percent, respectively, for the three rates. All indications were that indefinite survival of some waterstargrass could be expected even in the higher combined rates of fenuronTCA at 20 lb./acre and diuron at 4 lb./acre.

Two,6-dichlorobenzamide was tested on waterstargrass at rates of 1, 5, and 10 p.p.m. in three replications. The plants were 8 to 12 inches long and growing in 4-gallon capacity containers at the time of treatment. The plants were exposed to the herbicide for 1 week before the treated water was replaced. A response rating was made at 1 and 2 months after treatment. The percentage of regrowth was estimated after 6 weeks, and the plant material harvested and weighed after 10 weeks (table 9).

TABLE 9.--Response of waterstargrass after an exposure for 1 week to three rates of 2,6-dichlorobenzamide: 0 = no response, 10 = all dead, Clarkedale, Ark.[1/]

Herbicide (p.p.m.)	Response after--		Regrowth	Yield
	1 month	2 months		
			Percent	Grams
1.0	6	2	50	19.6
5.0	8	5	20	11.2
10.0	10	8	5	4.2
Control	0	0	100	33.2

1/ Averages of three replications.

The leaves of the waterstargrass were killed rapidly by the 2,6-dichlorobenzamide, which accounts for the high initial plant response rating. The meristem at the nodes of the plants was not affected so readily, and there was survival at all rates of application. All regrowth was by new shoot production from the surviving nodes. Plant survival was reduced as the dosage increased. Since some of the nodes were killed, it is likely that a longer exposure period would have provided better control.

Waterstargrass growing in 5-gallon capacity containers was treated with picloram at concentrations of 1 and 10 p.p.m. The plants were 8 to 12 inches long, in three replications, and growing vigorously at time of treatment. The plant response was noted at 24 and 72 hours after the herbicide was applied. The treated water remained in contact with the plants for 3 weeks. At that time a final response rating was made and the test terminated (table 10).

TABLE 10.--Response of waterstargrass following exposure for 3 weeks to picloram: 0 = no response, 10 = all dead, Clarkedale, Ark.[1/]

Herbicide (p.p.m.)	Waterstargrass response after--		
	24 hours	72 hours	3 weeks
1.0	0	3	8
10.0	1	6	10
Control	0	0	0

1/ Averages of three replications.

There was little plant response at 24 hours. After 72 hours there was a marked etiolation and dying of the plant stems, but the leaves remained green. After 3 weeks, the kill was complete in the 10.0 p.p.m. treatment while there was some survival at the 1.0 p.p.m. rate. The surviving material consisted of new shoots, of very poor vigor, from the old nodes.

Granular formulations of CIPC and the butoxyethanol ester of 2,4-D and 2,4,5-T were applied to waterstargrass at a rate of 20 lb./acre each. Waterstargrass cuttings were implanted into 2 inches of soil in 1-liter containers of water and permitted 2 weeks to initiate roots and begin growing. The herbicides were carefully weighed and applied to the soil in the treatment vessels. Six weeks after the materials were applied, a rating of the plant response was recorded. At that time all the pots were emptied, new soil added, and the plants washed and replanted into the untreated soil. One month later the plant material was harvested and the fresh and dry weights noted.

There was unmistakable response by the waterstargrass to all treatments, with 2,4-D being the most active (table 11). If all the herbicide had been released from the granules at once, the maximum concentration possible would have been approximately 200 p.p.m. Any survival following exposure to even a large percentage of this possible concentration for 6 weeks would indicate considerable tolerance of waterstargrass to these materials.

An experiment was established to study the effect of acrolein on waterstargrass. One inch of soil was added to 1-quart mason jars which were then filled with water. Sections of waterstargrass with roots were dropped into each jar. After 3 weeks the sections were rooted to the mud. The

TABLE 11.--Response of waterstargrass following 6 weeks' exposure to granular formulations of the herbicides listed: 0 = no response, 10 = all dead, Clarkedale, Ark.[1/]

Treatment	Rate	Response rating	Plant weight[2/]	
			Fresh	Dry
	Lb./acre		Grams	Grams
2,4-D, BE ester	20	9	0.7	0.16
2,4,5-T, BE ester	20	7	5.9	1.55
CIPC ----------	20	3	7.9	1.24
Control ----------	--	0	16.8	2.16

1/ Averages of four replications.
2/ Weighed 10 weeks after herbicides were applied.

acrolein was added to the jars and each covered with saran wrap. Six herbicide concentrations, seven periods of exposure, and five replications were utilized (table 12). After each period of exposure the treated water was removed from the jars designated and they were refilled with fresh water. Observations on the plant response were made independently by three observers at 1 and 2 weeks after initiation of the treatments.

Significant differences are not present at the 0 or 256 p.p.m. concentration levels over the hours of exposure at any exposure. Significant differences occurred at 1 p.p.m. between levels of hours of exposure. The trend indicated is that of increased control by greater concentrations at any hours of exposure or of increased control by longer periods of exposure at a given concentration level. However, a concentration of 16 p.p.m. or higher for 4 or more hours was required for a response rating of 7.0 or higher. Whether the water to be treated is static or flowing probably would have considerable influence on the rate of acrolein to be used.

TABLE 12.--The response of waterstargrass exposed to five concentrations of acrolein for the periods indicated. The ratings were made 1 and 2 weeks after the initial treatment: 0 = no control and 10 = plants dead, Clarkedale, Ark.[1/]

Rating after--	Hours exposure	Concentration (p.p.m.) 0	1	4	16	64	256	Average
1 week	1/16	3.92	3.58	4.54	5.66	7.32	8.18	5.533
	1/4	3.84	5.48	5.00	6.06	7.80	8.56	6.123
	1	3.12	4.08	4.66	5.26	6.76	7.40	5.213
	4	2.42	4.20	5.66	7.14	8.94	8.80	6.193
	16	3.20	3.40	6.14	7.48	7.72	8.34	6.047
	64	2.86	3.86	5.14	7.66	7.78	9.00	6.050
	256	3.86	5.14	4.68	6.00	8.74	8.00	6.070
2 weeks	1/16	2.78	2.66	4.40	5.52	6.34	8.26	4.993
	1/4	3.00	4.20	4.42	5.94	7.26	8.54	5.560
	1	2.86	2.78	4.52	5.62	7.18	8.14	5.183
	4	2.54	3.12	4.78	7.42	8.72	8.46	5.840
	16	3.02	3.04	5.12	7.68	7.92	8.72	5.932
	64	2.48	3.74	4.52	7.00	8.08	9.06	5.813
	256	3.20	4.40	4.18	6.72	9.00	8.34	5.973
Least significant difference for--							0.95	0.99
Means, subplots							1.256	1.657
Means, two concentrations							0.532	0.699
Means, two concentrations within 1 week							0.752	0.989
Means, two concentrations at 1 exposure period							1.410	1.854
Means, one concentration between weeks							0.851	1.204
Means, one concentration between exposure periods							1.562	2.067

1/ Each value is the average of five replications and each replication is the average of three independent readings.

DISCUSSION

It was concluded from the studies that waterstargrass is difficult to control in its natural habitat. The volume and movement of water influenced the lack of response to the systemic herbicides. In addition, the tolerance to herbicides, as exhibited by the meristem tissue, indicated that few of the systemic compounds tested could be used to economically control the weed even in closed bodies of water. Contact-type materials were more satisfactory, providing effective temporary control as a result of rapid deterioration of the plants.

For optimum control by systemic herbicides, the plant should readily absorb and translocate the herbicide. Funderburk and Lawrence[4/] showed that radioactive carbon (C^{14}) was translocated both acropetally and basipetally in waterstargrass. However, since there was no injury symptoms, there was no evidence that the labeled herbicides simazine and fenac were transported intact. Results of tests at Clarkedale showed that simazine was one of the more active materials on waterstargrass. Several of the tests described here indicate that the ability to translocate herbicides is very weak in waterstargrass. The study utilizing 2,4-D (table 7) left little doubt that the material was in the terminal portion of the plant. Yet, an increased response basipetally was exhibited only by an increase in dosage.

Indications of absorption and translocation in waterstargrass were not consistent between different compounds, leading to possible biochemical implications. Three days after application of picloram, there was marked etiolation of the plant stems while the leaves remained green. Conversely, 2,6-dichlorobenzamide caused a quicker kill of the leaves with a slower response in the stems. Several materials were sufficiently absorbed by waterstargrass to cause deterioration of all tissue except the nodal meristem, which ultimately supported regrowth. Two,4-D was consistent in its failure to kill all the nodal meristem. Simazine and picloram showed the most activity on the meristem tissue. Funderburk and Lawrence[5/] reported that 2,4-D, ametryne, prometryne, and fenac showed slight movement from the shoot to the root in waterstargrass but no movement from the root to the shoot. The BE ester of 2,4-D showed both up and down movement but was transported more readily downward. Paraquat and diquat showed no appreciable movement in either direction. The work of Funderburk and Lawrence also revealed that radioactive phosphorus (P^{32}) was transported in both directions, with the greatest movement from root to shoot. With movement in either direction, there was a definite accumulation of P^{32} in the nodal areas. This tendency to an accumulation of material in the nodal areas is consistent with the more obvious responses of waterstargrass to herbicides, the etiolation and growth malformation of the nodal meristem. However, it is not consistent with the plant's survival by regrowth from the affected nodal area. Systemic materials that show promise for the control of waterstargrass in nonflowing water are 2,6-dichlorobenzamide, diuron, CP-522, DSMA, endothall, and fenac.

The response of waterstargrass to herbicides together with observations on its ecological and physiological aspects indicate that the weed may be more economically controlled by contact toxicants. In areas where the weed is likely to be a pest, its natural requirements are such that it may or may not appear.[6/] This precludes the need for planning pretreatments against an

---

4/ Funderburk, H. H., Jr., and Lawrence, J. M. Preliminary studies on the absorption of C^{14} labeled herbicides on fish and aquatic plants. WEEDS 11(3): 217-219. 1963.

5/ Funderburk, H. H., Jr., and Lawrence, J. M. Absorption and translocation of radioactive herbicides in submersed and emersed aquatic weeds. Weed Res. 3(4): 304-311. 1963.

6/ See footnote 3.

infestation. Once the weed is established, remedial measures are needed at once. In field tests, acrolein was effective in rapidly clearing a stream of vegetation and providing adequate temporary control (fig. 1). The high initial cost together with the resistance and slow response of waterstargrass to systemic materials make application of such compounds undesirable. On the other hand, some materials with contact activity are economical and provide rapid disintegration of the herbaceous waterstargrass. Application of contact herbicides is usually not as restricted by flowing water as are systemic herbicides. Some of the more promising contact materials tested were acrolein, diquat, aromatic oils, and the emulsified O-dichlorobenzene.

CONCLUSIONS

1. Waterstargrass exhibited a resistance to herbicidal control caused, probably, by both poor translocation of the materials and by a natural tolerance of the nodal meristem tissue.

2. The presence of waterstargrass in flowing water restricted the contact time for systemic herbicides and limited their use for control of the weed.

3. The use of contact toxicants is indicated, both in flowing and nonflowing water, for the most rapid and economical control of waterstargrass.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Beltsville, Maryland 20705

Postage and Fees Paid
U.S. Department of Agriculture

Official Business